

FIELDBUS INTEGRATION TO THE REALTIME ETHERNET STANDARD PROFINET

Juergen Jasperneite *

* *PHOENIX CONTACT Electronics GmbH*
31812 Bad Pyrmont, Germany
jjasperneite@phoenixcontact.com

Abstract: For the investment protection of installed plants and machines suitable concepts for the integration of Fieldbus systems to future Realtime Ethernet Networks are very important. In this paper a approach for the integration of the fieldbus system INTERBUS into the Realtime Ethernet standard PROFINET IO will be presented. It shows that it is possible despite very different device models to realize a deep integration.
Copyright ©2005 IFAC

Keywords: Realtime Ethernet, PROFINET, Fieldbus, INTERBUS

1. INTRODUCTION

For many applications Realtime Ethernet becomes an alternative to fieldbus systems. This is due to a decrease in price provoked by the office Ethernet market, high bandwidth, switching technology (IEEE, 1998a), priority features (IEEE, 1998b), full duplex operation (IEEE, 1997), availability of Ethernet bridges as well as Ethernet-enabled products fulfilling industrial environmental requirements (e.g. (Phoenix Contact, 2005)). One of the most promising Realtime Ethernet standards is PROFINET (Feld, 2004). For reasons of investment protection and a simple migration path, the fieldbus systems PROFIBUS (PNO, 2005) and INTERBUS (IB Club, 2005) use PROFINET as the common integration platform. This corresponds to a central requirement of the association of the German Automotive industry (VDA), who use both fieldbus systems in their plants. The VDA asked the automotive providers to develop common solutions based on Ethernet.

In the following a fieldbus integration concept for INTERBUS in PROFINET will be described that also is applicable for other fieldbus systems.

The paper is organized as follows: Section 2 and 3 give a brief introduction to INTERBUS and PROFINET.

Afterwards a description of the proxy architecture follows in section 4. In section 5 the implementation of the mapping between INTERBUS and PROFINET is presented. The paper ends with the conclusions.

2. BRIEF INTRODUCTION TO INTERBUS

INTERBUS is an international standardized fieldbus system according to IEC-61158 (type 8) (IEC, 2001). It has been designed as a fast sensor/actuator bus for transmitting process data in industrial environments with 7.5 Mio. installed nodes (status: Q1/2005). Due to its transmission procedure and ring topology, INTERBUS offers features such as fast, cyclic, and time-equidistant process data transmission, diagnostics to minimize downtime, easy operation and installation, as well as meeting the optimum requirements for fiber optic technology. The INTERBUS master/slave system enables the connection of up to 512 devices, across 16 network levels. Unlike in other systems where data is assigned by entering a bus address using DIP or rotary switches on each individual device, in the INTERBUS system data is automatically assigned to devices using their physical location in the system. In the INTERBUS system, data is transmitted according to the summation frame method. INTERBUS has

a ring structure. The ring structure allows INTERBUS to send and receive data simultaneously. The master controls all devices of an INTERBUS system. The protocol architecture of INTERBUS provides the cyclic process data channel (PD) and an acyclic parameter data channel, using the services of the Peripheral Message Specification (PMS). It is also possible to exchange safety-related data in INTERBUS cycles in addition to standard data. This is done by a special safety protocol layer on top of the PD-channel. INTERBUS uses the bus-independent xml-based device description FDCML (Fieldbus Description Configuration Markup Language), according to ISO 15745-3 (FDCML, 2005). FDCML enables the different views of a field device to be described due to the generic device model used. Some examples include identification, connectivity, device info functions, diagnostic information, and mechanical description of a device. In configuration software, this electronic device description is used for configuration, startup, and other engineering aspects. More details about the INTERBUS system can be found at the home page of the INTERBUS Club (IB Club, 2005).

3. BRIEF INTRODUCTION TO PROFINET

PROFINET is an initiative to emerge Ethernet to the next generation of industrial automation (Feld, 2004). PROFINET consists of several topics such as distributed automation (PROFINET CBA), decentralized field devices (PROFINET IO), network management, installation guidelines and web integration. All these different topics will help to make standard switched Ethernet (IEEE, 1998a), (IEEE, 2000) easier to use in industrial automation.

PROFINET IO enables the use of decentralized field devices with Ethernet. With decentralized field devices all automation devices including IO-devices, valve islands, frequency converter etc. can easily be used in a homogeneous network infrastructure. PROFINET IO defines three different types of functionality:

- The IO controller is a controlling device which is associated with one or more IO devices (field devices).
- The IO device is a field device and performs the following activities depending on the functionality.
- The IO supervisor is an engineering device which manages provision of configuration data (parameter sets) and collection of diagnostic data for/from IO controllers and/or IO devices.

PROFINET IO offers a cyclic exchange of more than 1000 inputs and outputs with 32 field devices in less than 1 ms. The data exchange is based on a provider/consumer mechanism. PROFINET IO allows a mono-controller or multi-controller operation, where more than one IO controller can be associated to one

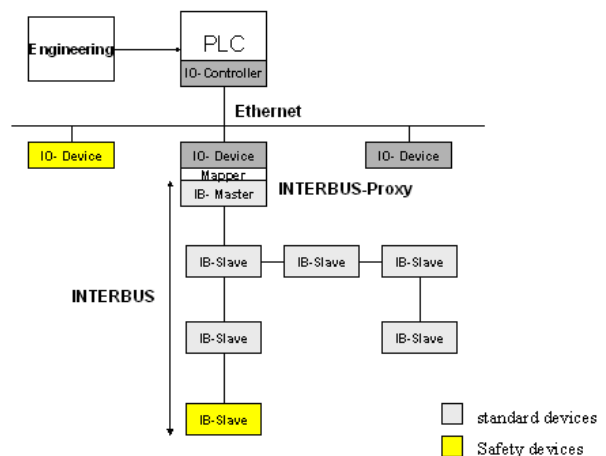


Fig. 1. INTERBUS Integration to PROFINET

IO device. Also an isochronous mode with a jitter less than 1 microsecond signalling to the application is specified. For engineering aspects of the field devices, PROFINET uses the xml-based device description GSDML (Generic Station Description Markup Language).

4. PROXY ARCHITECTURE

The concept of a fieldbus integration must consider the following aspects:

- Exchange of cyclic process data, acyclic parameter, alarms : This are basic functions of field level communication.
- Functional safety : The specifications of field bus systems are extended by the characteristics of safe data communication. This characteristic must be given also in the combination of realtime Ethernet and Fieldbus. This requirement will not be considered in this paper, because the safety layer of PROFINET is still under discussion.
- Diagnostics : E.g. INTERBUS has superior diagnosis mechanisms for bus diagnosis. This characteristic must be preserved in a heterogeneous network.
- Temporal behavior: The end-to-end latency must not exceed the requirements of factory automation (typical range between 5..10 ms).
- Bus configuration: Each bus system has specific configuration parameters.
- Engineering aspects: The user demand only one configuration tool.

From the networking point of view the proxy represents a gateway between the Ethernet-based PROFINET system and the fieldbus system (see Fig. 1).

For the integration of a fieldbus system to PROFINET two modeling concepts exists:

- Multi-device approach: mapping fieldbus devices to logical PROFINET-IO devices
- Slot/Sub-slot approach: mapping fieldbus devices to the model of a modular slave

4.1 Multi-device approach

With the multi-device approach (see Fig. 2) it is possible to realize several logical IO devices and IO controllers within one physical device. To do this, some additional protocol elements are defined for the context management, which is based on a connectionless Remote Procedure Call (RPC). The 16 Byte protocol elements 'Interface-UUID', 'Type-UUID' and 'Object-UUID' are defined for structuring the RPC-interface and can be used for addressing different logical IO devices or IO controllers within one physical device. The main disadvantage of this approach is, that for every logical device, a separate Ethernet frame will be used. This becomes very inefficient, if the number of IO channels per fieldbus node is be very small.

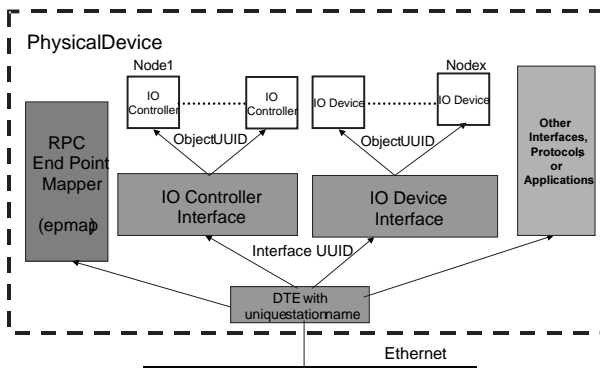


Fig. 2. Multi-device model of PROFINET IO

4.2 Slot/Sub-slot approach

Another kind of modelling devices in PROFINET-IO is the slot/sub-slot approach, which is used for modular slaves. The IO device is composed of different structural units to group application objects and provide a certain level of abstraction. These structural units may reflect hardware components or virtual functional units of the field device. The aim is to provide a suitable set of address parameter. These structural units are referred to as slots, subslots, and channels which may reflect also physical units, sub-units, or a single connection point of a IO device. Figure 3 shows the structure of this model. The structural units slot and subslot are accessed by means of slot number or subslot number within the PROFINet IO address model. Slot 0 in combination with a particular Subslot (e.g. 1) must always be used to represent the IO device itself referred to as Device Access Point (DAP). A DAP contains the global data of an IO device. Furthermore, the subslot Number 0 in combination with a particular Slot Number shall represent the dedicated module itself. This definition implies that a "real" subslot 0 does not exist and must not contain IO channels. A slot, in most cases slot 0, may contain up to 16 further special subslots referred to as Interface subslots. These subslots define the remote access to

IP address parameters and the station name. A slot, in most cases slot 0, may contain for each interface up to 255 subslots referred to as port subslots. This

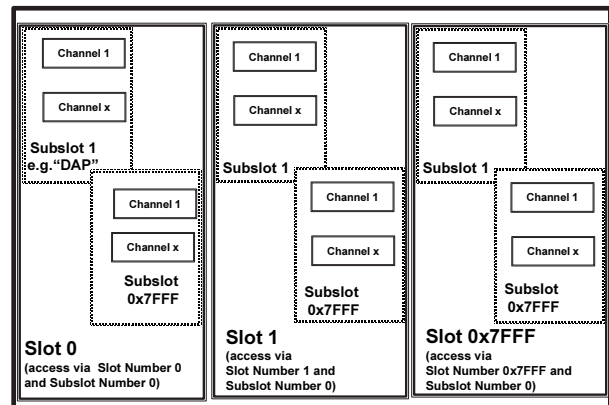


Fig. 3. Slot/Sub-slot model of PROFINET IO

approach use only one Ethernet frame per device and is therefore more efficient than the multi-device approach.

5. IMPLEMENTATION

In this section we describe the implementation of a INTERBUS proxy. Because of its better performance we prefer the mapping of field devices to a modular slave.

Figure 4 shows the internal structure of the proxy device that realizes the mapping between PROFINET IO and INTERBUS. A INTERBUS master offers the functionality of the connected slaves through the following logical interfaces:

- Network Management: This interface is used to manage the INTERBUS-configuration. There are functions to load and activate the expected configuration, to activate or deactivate devices, etc. These functions are available by a special communication protocol called "mailbox protocol". This protocol runs over a defined interface called mailbox interface (MXI).
- Process Data Channel: Via this interface the cyclic IO data values of all INTERBUS slaves can be accessed. There are mechanisms for asynchron or synchronized data exchange.
- Parameter Data Channel: The parameter data channel can be used to access the functionality of the acyclic parameter data transmission between the INTERBUS master and the INTERBUS slaves. This functionality is also available by the MXI.

The services of a PROFINET IO device are offered by the following application service elements (ASE), as defined in ISO/IEC 9545. This ASEs are relevant for the use of a underlying INTERBUS-System.

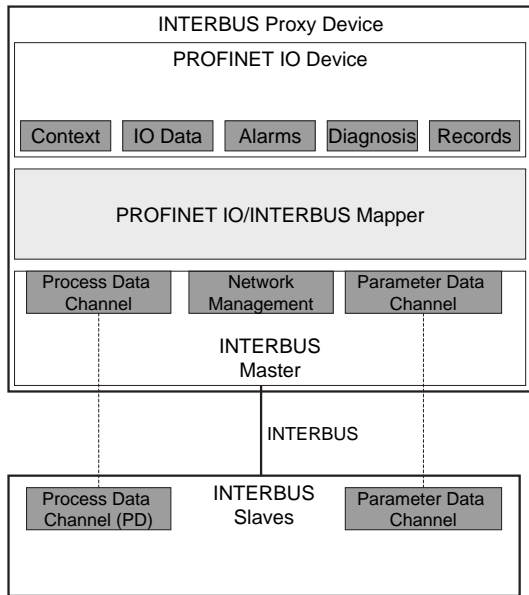


Fig. 4. Architecture of the proxy device

- Context: services to handle the configuration of a modular slave as expected configuration, connected configuration, identification differences, etc.
- IO Data: services to exchange cyclic IO data and status information of IO data.
- Alarm: services to send and receive acyclic alarms.
- Diagnosis: services to read and write device diagnosis.
- Record data: services to read and write device-dependent parameter data.

The task of the PROFINET IO/INTERBUS mapper is to intercede between this interfaces in several use cases such as cyclic data transfer, startup, bus error.

5.1 Description of the Mapping between PROFINET and INTERBUS

The mapping of INTERBUS to PROFINET IO is realized on top of the well-defined slot/sub-slot model (see Fig. 5). Therefore it is possible to see INTERBUS as an application profile of PROFINET IO. Slot 0 is reserved for the DAP module, while slot 1 is used for the INTERBUS master. The module ID number is used to categorize different possible implementations of a INTERBUS-Master. Slot 1 only contains the subslot 1, because presently it is not possible to define more than one subslot in the GSDML device description . It is useful to have more subslots in GSDML to differentiate the master functionality. The Input data of Slot 1 are used to define the diagnostic-registers of the INTERBUS master. These registers are important for migration reasons, because all INTERBUS users are familiar with the handling of these registers in PLC applications. The following registers are mapped to input data items:

INTERBUS Proxy Device			
	Slot 0 (Proxy)	Slot 1: INTERBUS Master	Slot 2..n: INTERBUS Slaves (1..n)
	Subslot 0 (DAP)	Subslot 0 (DAP)	Subslot 1 (IB Device)
Input-data		Diagnostic Registers IOPS/IOCS	Device Inputs IOPS/IOCS
Output-data		Control Registers IOPS/IOCS	Device Outputs IOPS/IOCS
Diag		Channel: Master Error Channel: User Error	Channel: Channel Error Channel: Periph Error
Alarm		Diagnosis: Channel Error	Diagnosis: Channel Error Plug/Pull
Record data		Dynamic MXI	GSDML:Buslevel GSDML:Alternative No.

Fig. 5. Mapping of INTERBUS to PROFINET-IO

- Diagnostic Status Register (unsigned16): This register contains the current status of the INTERBUS-System. There are defined bits for bus errors, peripheral faults etc.
- Diagnostic Parameter Register (unsigned16): This register contains more information about special error conditions. As one example, it contains the slot number of the erroneous module in case of a bus error.

The Output data of Slot 1 are used to define the so-called standard function registers of INTERBUS. The following registers are mapped to output data items:

- Standard Function Start Register(unsigned16): This register contains single bits to trigger some INTERBUS functions like acknowledgement of bus errors or to activation/deactivation of single devices
- Standard Function Parameter Register (unsigned16): This register contains more information about some actions, needed by the standard functions as explained above. E.g. it contains the slot number of the module that has to be activated or deactivated.

INTERBUS errors and diagnosis alarms are mapped to the PROFINET-IO channel diagnosis and alarm functionality. As mentioned before, INTERBUS defines a communication channel, called MXI. Via this MXI the user is able to control all possible functions of an INTERBUS master. This mailbox interface will be mapped to a dynamic record data item, that can be written and read from the user application.

The slots 2..n are mapped to the functionality of the INTERBUS slaves. The slot number therefore corresponds with the physical position of the INTERBUS device. The INTERBUS process data are directly mapped to the corresponding data items of PROFINET IO.

INTERBUS has superior diagnostics mechanisms for bus diagnosis. The usage of this diagnostics features in PROFINET IO are very important. The following INTERBUS errors are mapped to the PROFINET channel diagnostics of the Slots 2..n:

- Channel Errors: INTERBUS has a built-in mechanism for the transmission of channel errors. These channel errors can be directly mapped to the appropriate channel error mechanisms of PROFINET IO.
- Peripheral Errors: Another class of INTERBUS errors are the so-called peripheral errors. This error class is used by device manufacturers to handle situations like "fuse blown". The extent of this mechanism is not very high. When integrating INTERBUS into PROFINET IO, a better mechanism can be achieved as described below. In the event of a peripheral error the provider status and consumer status of the affected module are set to bad.
- Localized Bus Errors: All bus errors are mapped to corresponding channel errors. In the event of a bus error the provider status and consumer status of all modules are set to bad, because there is no data transfer in the INTERBUS system.
- Device Channel Diagnostics: INTERBUS has no standard mechanism for device diagnosis as defined in PROFINET IO. In this way, it is straightforward to extend the INTERBUS to a similar mechanism. The basis of this mechanism is the PCP communication with a correlative profile. Using this feature an INTERBUS device manufacturer is able to generate channel diagnostics that is fully compatible to PROFINET IO.

For prototyping, the PROFINET stack and the PROFINET/INTERBUS mapper was implemented on a ARM-7 processor (40 MIPS) with the realtime operating system PSOS. The time-critical process data of the maximum permissible number of INTERBUS nodes could sent within the same PROFINET frame. Thereby a high consistency and high performance of the process data image is ensured. With the used hardware platform a PROFINET send clock of 2 ms could be achieved.

6. CONCLUSIONS

For many applications Realtime Ethernet becomes an alternative to fieldbus systems. For reasons of investment protection, a migration path from the first generation of fieldbus systems towards Realtime Ethernet is necessary. By the example of INTERBUS, we

introduce a integration concept for fieldbus systems to the Realtime Ethernet PROFINET standard. With the approach described here, it is possible to configure and operate the fieldbus system without further fieldbus-specific engineering tools. It was shown that with the used modelling approach it is possible to integrate all characteristics of the fieldbus system into the PROFINET network. In combination with the concepts for distributed automation PROFINET CBA and decentralized field devices PROFINET IO all customer requirements concerning openness, migration of fieldbus systems and standardization are fulfilled. In the next step the necessary measures for functional safety must be integrated.

REFERENCES

- FDCML (2005). *Device description language*. www.fdmcl.org.
- Feld, Joachim (2004). PROFINET- Scalable Factory Communication for all applications. In: *5th IEEE International Workshop on Factory Communication Systems (WFCS'2004)*. Vienna.
- IB Club (2005). *INTERBUS Club*. Blomberg. www.interbusclub.com.
- IEC (2001). *Digital data communication for measurement and control – Fieldbus for use in industrial control systems*. IEC 61158 Ed.3 CDV, Type 8 (INTERBUS).
- IEEE (1997). *Specification for 802.3 Full Duplex Operation*. IEEE. New York. ANSI/IEEE Std. 802.3x.
- IEEE (1998a). *Media Access Control (MAC) Bridges*. IEEE. New York. ANSI/IEEE Std 802.1D-1998.
- IEEE (1998b). *Virtual Bridged Local Area Networks*. IEEE. New York. ANSI/IEEE Std 802.1Q-1998.
- IEEE (2000). *Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*. IEEE. New York. ANSI/IEEE Std 802.3-2000 Edition (ISO/IEC 8802-3:2000(E)).
- Phoenix Contact (2005). *Industrial Ethernet Products*. www.ethernetrail.com.
- PNO (2005). *Profibus Nutzer Organisation*. Karlsruhe. www.profibus.com.